CONCRETING IN WINTER

PUBLISHED BY THE

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS

BELLEVUE COURT BUILDING, PHILADELPHIA

A REQUEST TO THE READER

FREE HELP

SHOULD you find this bulletin helpful in building with concrete, we would consider it a favor to have you so inform us. Likewise, we would appreciate a description (and a photograph, if possible) of what you have built. In this way you will assist us in aiding others in the same way we trust we have helped you.

If you do not fully understand any part of this book, or if you desire further information, we would be glad to have you write to the

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ONLY a few years ago building construction necessitating concrete work was, by common consent, stopped on the approach of cold weather.

But many large contracting companies, who have carried on their concrete work uninterruptedly with results as satisfactory as obtained during more favorable weather conditions, have proved that concreting is possible during periods of freezing weather if proper, simple precautions are taken. A knowledge of this has made the subject of concrete construction in winter of general interest to many users of cement; in fact, since it is a slack season many have found winter the best time of year for them to build with concrete. However, successful results depend upon exercising certain additional precautions beyond those that must be observed during other seasons of the year. The object of this publication is to describe methods that should be followed to insure success in concreting carried on during cold weather.

Advantages

Contractors were probably the first to recognize the advantages resulting from being able to continue concreting without interruption during the winter. Tools and machinery were thus kept employed instead of being idle for three or four months. Overhead expenses and depreciation, being distributed over the cost of a greater volume of work, were considerably reduced. Capable and faithful employees, developed into an efficient organization, were retained for more active service in the spring.

With the possibility of carrying on work during the winter, these troubles are largely eliminated. Materials can be promptly delivered because railroads and supply houses are, as a rule, not so rushed during the winter as in the summer when all building operations are active. Another decided advantage is that the owner need not suffer any delay in the completion of the work, consequently can utilize his buildings in the usually more active spring and summer seasons.

Disadvantages

If such precautions as will be described later are followed, probably there is but one disadvantage to carrying on concrete work during freezing temperatures—that is the slightly increased cost of the resulting construction. This comes from the expense involved in applying necessary precautions and from the slightly reduced efficiency of workmen when more or less exposed to the elements. Although this increased cost may be from 6 to 10 per cent, perhaps greater, it rarely exceeds the latter figure; and when early occupancy of a structure is the essential reason for carrying on the work time saved usually more than offsets any increase in cost.

Freezing of Concrete Must be Prevented

Although claims are sometimes made that concrete frozen before hardening may not suffer permanent injury if upon thawing it is not again exposed

Fig. 1.—Heated Water Being Discharged Directly Into Mixer.

to freezing weather until sufficiently hardened to be unaffected by such exposure, nevertheless every precaution should be taken to prevent freezing. If this is guarded against for at least five days, the danger of injury from subsequent freezing may be assumed to have passed.

To insure that concrete will have sufficient heat to assist in hastening early hardening, materials and water should be heated so that the concrete when deposited will have a temperature not lower than 80 degrees Fahrenheit. Heat given to concrete by heated water and heated sand and gravel or broken stone, and afterward maintained by proper protection when the concrete has been deposited, is increased by heat developed within the concrete during the period of early hardening of the cement. Not only does the heating of aggregates and water hasten the development of this internal heat, but the temperature of the concrete is increased somewhat above that prevailing when concrete is deposited under the usual summer weather conditions; and these factors combined help to maintain the temperature of the freshly deposited concrete above freezing.

Properly hardened concrete and frozen concrete often look alike on casual inspection. For this reason extreme care must be taken when removing forms from concrete which has been exposed to freezing weather. Forms must be left in place until the concrete has obtained sufficient

FIG. 2.—HEATING MIXING WATER BY EXHAUST STEAM. Note water tank at top of mixer.

strength to be self-supporting or to support imposed loads. Frozen concrete can be detected by pouring hot water on the surface or applying heat from a painter's or plumber's blow torch. If the surface becomes soft after application of hot water or upon exposure to heat from a torch, there is good evidence that the concrete is frozen, and forms should not be removed.

Although concrete is exposed to greatest danger when the temperature is below freezing, nevertheless precautionary measures consisting of heating materials and water should be taken when the temperature drops to 40 degrees, because of the assistance that this added heat will be in accelerating hardening. Such measures are also a protection against a sudden drop in temperature, which is quite likely to occur when prevailing temperatures are as low as 40 degrees.

Methods of Protection

Several methods are commonly employed to afford the necessary protection against freezing to freshly deposited concrete. In the following paragraphs these are described separately; but one should remember that none of these methods is commonly employed alone; usually they are combined, that is, merely covering freshly deposited concrete placed in cold forms and mixed with unheated materials and water which have a temperature near

FIG. 3.—HEATING STONE PILE WITH STEAM. Canvas covering to retain all heat possible.

freezing, is not sufficient, as the concrete is likely to freeze at once. Just how many of the protection methods need be combined and used depends upon the character of the work and the conditions under which it is being carried on.

Use of Salt in Mixing Water

Because cheap and simple to use, the practice of adding common salt to the mixing water was probably the first and most popular method employed to prevent freezing of freshly deposited concrete. In present practice, however, the use of salt is declining. Salt simply lowers the freezing point of the mixing water. In no way does it hasten the hardening of the concrete; in fact, it causes the concrete to harden more slowly. Furthermore, the result of using salt up to the safe limit affords protection against only a moderate degree of cold.

Rules for the use of salt have been formulated, the most widely accepted one being that which called for its addition to the mixing water in an amount equal to one per cent of the weight of the water for each degree of temperature below freezing point to be counteracted; and as not more than 10 per cent can safely be used without probability of impairing the

Fig. 4.—Method of Heating Sand.

strength of concrete, salt affords protection only for temperatures above 22 degrees; that is, for a range of 10 degrees below freezing.

Experiments seem to indicate that the presence of salt in concrete is particularly objectionable in reinforced construction, inasmuch as corrosion of the steel results; and as this corrosive action increases as the percentage of salt is raised the use of salt is not to be recommended in reinforced construction. If used at all, its use should be confined to plain mass work under conditions where the temperature is not likely to drop more than a few degrees below freezing, and where the appearance of the finished work will not be marred by the resulting efflorescence that is common to work in which salt has been used.

Several other substances have been recommended or employed in the same manner that salt is used to lower the freezing point of concrete. Among these is calcium chlorid; alcohol and glycerin also would produce a similar action in lowering the freezing point. Calcium chlorid presents the same objections mentioned for salt, and alcohol and glycerin may be considered impractical on account of cost—while the general objection of lowering the freezing point without hastening the hardening of the concrete applies to all of these materials. In cold weather the object to be attained is a hastening of the hardening action and this cannot be accomplished without heat.

FIG. 5.—HEATING STONE WITH SHEET IRON CYLINDERS. Workmen are digging trench for placing additional cylinders.

Heating of Materials

This preventive measure is undoubtedly the most effective one leading to safe and satisfactory results. The heat given to the concrete through this method accelerates hardening and early strength of the concrete, and exerts no injurious effect on the final strength. If heating of materials is properly done and the concrete quickly deposited and protected before the added heat can be lost, the concrete will harden almost as rapidly during freezing temperatures as at other times of the year, and will ultimately acquire the same strength as if placed during summer weather.

Heating Water

Mixing water is the easiest of the materials to heat. A temperature averaging 150 degrees can easily be secured and maintained. Two methods are in most general use for heating mixing water. One is by means of live or exhaust steam from a boiler plant on the job, and the other is to heat the water in tanks or kettles over a fire. On large jobs heating by steam is the method commonly employed. There are now available a number of devices similar to the ordinary steam-boiler injector which lift and, at the same time, heat the water by passing it through a mixing valve where it comes in contact with live steam. Two pipes lead to the valve, one

Courtesy Turner Const. Co.

FIG. 6.—CONCRETE FLOOR COVERED WITH CANVAS SUPPORTED SHORT DISTANCE ABOVE IT. Heat from salamanders raises temperature of air in this space.

carrying steam and the other cold water. After passing through the valve the heated water is discharged into a tank usually placed on the concrete mixer, or may be discharged directly into the mixer if the discharge pipe is equipped with a measuring valve. (See Fig. 1.)

Exhaust steam from the boiler operating the mixer is often allowed to discharge into a water tank located above the mixer, thus raising the temperature of the water. (See Fig. 2.) Such a tank is usually equipped with a float mechanism to measure the correct amount of water for each batch of concrete; but this arrangement is often unsatisfactory because not enough water can be heated to the desired temperature before required for the next batch. In such cases additional tanks or barrels must be provided to insure a sufficient supply of heated water. Exhaust steam is not so effective as live steam because naturally of lower temperature, neither can the supply be so easily regulated.

Perhaps the method used to a greater extent than any other is to install in a water-barrel or tank a steam-pipe or short coil connected with the boiler plant of the mixer. This arrangement is easily cared for and regulated, and gives the best average results. On small jobs where a steam-power mixer is not employed, a tank or large kettle supported above a fire

FIG. 7.—PROTECTING NEW-LAID SIDEWALKS AGAINST POSSIBLE DROP IN TEMPERATURE DURING THE NIGHT.

may be used. This method, however, is not satisfactory when large quantities of mixing water are required, and is not so convenient as heating with steam, because continual attention is required to keep a proper fire under the tank or boiler.

Heating Sand and Gravel or Stone

In freezing weather aggregates contain considerable frost and sometimes lumps of snow and ice. Such frost and frozen material not only chill the concrete, even though the water used may have been heated, but also prevent thorough mixing. Therefore, sand and gravel must be thoroughly thawed out by heating; although the temperature should not generally be raised above 150 degrees.

Practically the same methods are used both for heating sand and gravel or stone. Sometimes the sand and stone are heated by steam by placing tarpaulins over the piles, thrusting pipes in the piles of material to be heated, and turning steam into the pipes. (See Fig. 3.) Another method consists of piling the material around and on top of some kind of a furnace—usually

Courtesy Turner Const. Co.

FIG. 8.—CANVAS HOUSING PROTECTING FRESH CONCRETE.

improvised from a sheet-iron cylinder such as an old smokestack, a section of an old iron sewer-pipe or culvert, or an old boiler. (See Fig. 4.) A fire is built within and the aggregate piled around and above the stove thus made. This is a very simple and inexpensive method, and is employed with satisfaction upon jobs of moderate size. There may be one disadvantage to this method: Unless the material in the pile is constantly turned or raked over, the particles nearest the fire may be heated too much and perhaps injured, while those farthest away at the top and sides of the pile may be hardly thawed out; also the dumping of fresh supplies of materials is somewhat hindered. (See Fig. 5.)

Steam heating of aggregates is undoubtedly the most suitable method when steam supply is available. There is no danger of overheating and consequent injury. A boiler pressure of 25 pounds is sufficient, and in some cases an old boiler that is no longer safe for high steam pressure may be used. When the steam heating method is employed for sand and stone, the materials may be heaped on coils of steam pipe through which steam

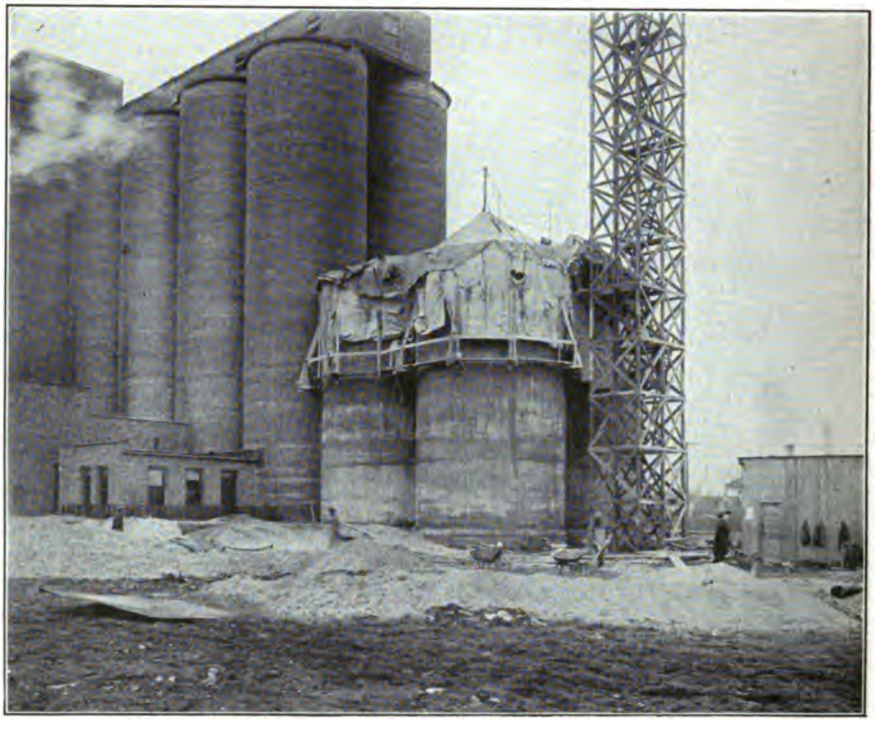

FIG. 9.—CANVAS HOUSING ON CONCRETE GRAIN BINS. Space under canvas kept warm with salamanders. Concrete mixed by hand beneath this protection.

circulates or lengths of pipe with open ends may be thrust into the piles as already suggested. In the latter case best results will be secured if the pipes are drilled with small holes every 18 inches, thus causing the steam to be distributed through a greater volume of the pile. Steam pipes when used as suggested do not interfere with the dumping of additional supplies of material and can be readily shifted about as may be necessary.

Heating Cement

Cement being only a relatively small portion of the concrete mass need not be heated.

Heating Forms and Reinforcing Steel

All ice and frost must be removed from forms before placing concrete. This can readily be accomplished by turning a jet of steam against the face of the forms which will not only remove ice and frost but at the same time heat the forms and reinforcing steel. This is essential because much of the

Courtesy Turner Const. Co.

FIG. 10.—SALAMANDERS IN USE. Notice housing in background covering window spaces.

heat given to the concrete by the heated materials would be lost if the concrete were deposited in the cold forms.

Protection of Concrete After Depositing

Concrete mixed with heated materials and left unprotected would naturally soon lose much of its heat if exposed to low temperatures and might even freeze at least on the surface, even though the materials had been heated. Although all concrete must be protected immediately after depositing in freezing weather, some classes of construction require more thorough safeguarding than others. For instance, thin floor slabs (see Fig. 6), beams, columns, sidewalks and similar construction have a large surface area in comparison with their volume, therefore they require more careful protection than need be given to foundations, abutments, and similar mass construction, where the excavation or bulk of the mass and heavy forms afford part of the necessary protection.

Floors are usually protected by a 12-inch layer of hay or straw. In such a case the concrete should first be covered with building paper or

FIG. 11.—SALAMANDERS IN USE ON FINISHED FLOOR.

canvas before placing the protective covering, and in outside work the straw should be weighted down with short boards to prevent the covering from being blown away. Such protective covering should be placed with special care, particularly where the concrete is exposed to unusual conditions, as where the floor is at the top of a building. Sidewalks, also, must receive extra care if successful results are to be obtained. (See Fig. 7.) Walks expose a large surface area to cold winds and the concrete must be well covered with straw or hay, or else housed in by means of a frame and canvas covering, and suitable temperature maintained by steam or salamanders.

After forms are in place for the construction of each floor of a building, the structure is usually housed in by canvas as shown in Fig. 8. Sometimes the canvas is supported by frames to oppose resistance to the wind. When the housing is to be exposed to high winds and is to remain in place for a considerable time, light sheathing boards, instead of canvas, are often used to enclose the construction. An ingenious method of enclosing was used in connection with the building of the National Tire and Rubber Co. at Palestine, Ohio. (See Fig. 12.) Frames 6 feet wide and 14 feet long, covered with heavy waterproof paper, were nailed to the forms and provided an easily erected and tight enclosure. The cost of this method of enclosing as given in the *Engineering Record* for January 9, 1915, was 2.1 cents per square foot in place. Salamanders are kept burning within the enclosure until the concrete has hardened sufficiently to stand exposure to any temperature. (See Fig. 9.)

Salamanders are open, sheet-iron, coke-burning pots used as stoves, and give off no smoke. Under ordinary conditions one salamander is provided for each 500 square feet of floor surface. (See Fig. 10.) To maintain the desired protection, provided the housing in of the structure has been properly done, an average of 150 pounds of coke will be burned for each twenty-four hours. By means of salamanders the temperature of an interior (See Fig. 11), when effectively enclosed by canvas or sheathing, can easily be maintained at about 65 degrees. This not only allows the concrete to harden under practically normal conditions, but adds considerably to the comfort of workmen that may be employed in the building. Salamanders are usually kept in operation from five to seven days on each floor. Experience has shown that the cost of operating them, including fuel and labor necessary to keep fires burning, ranges from 70 to 80 cents per day of twenty-four hours.

Removal of Forms

One other important precaution should be observed in connection with cold weather concreting: In spite of the fact that materials may have been heated and the temperature kept as high as possible, nevertheless it is practically impossible to uniformly maintain temperature conditions as they normally prevail in summer.

In connection with the effect of low temperatures on the setting of concrete, Dr. A. S. Cushman, of the Institute of Industrial Research, after a series of tests, states: "It will be noted that low temperature and high humidity retard the setting of Portland cement concrete. When the normal percentage of water is increased, the setting of the cement is further retarded, but where the normal percentage of water is decreased, a curve is obtained lying between the normal percentage of water at low temperature and the normal percentage of water at normal temperature. The points obtained for this curve, however, are more erratic than in any of the other series, this being due to the extreme difficulty of tamping the dry concrete uniformly in the different molds. While indications point to the fact that a dry concrete will set up more rapidly under conditions of low temperature and high humidity than a normally wet or sloppy concrete, great caution should, nevertheless, be exercised to see that the concrete is made as dense as practicable."

Concrete deposited during freezing weather will not harden as quickly as in warm weather; therefore, forms must be left in place longer than they would be allowed to remain in summer. This often requires that, particularly in floor construction in reinforced concrete buildings, extra sets of forms be provided to prevent delay in prosecuting work. Removing forms at too early a period is to be condemned in connection with all concrete work, regardless of weather conditions, but deserves particular emphasis in connection with cold weather work. Any additional money that may be saved as the result of removing forms a day or two ahead of the safe time is often disastrously offset by failures that could have been prevented by leaving them in place a day or two longer.

Courtesy Engineering Record

FIG. 12.—USE OF PAPER-COVERED FRAMES FOR ENCLOSING BUILDING.

If instructions contained in this booklet are strictly observed, there will be no danger of frozen concrete nor any trouble experienced in concreting during freezing weather.